**3GPP TSG RAN WG1 #109-e R1-2205363**

**e-Meeting, May 9th – 20th, 2022**

**Agenda item:** 9.10.2

**Source:** Moderator (NTT DOCOMO, INC.)

**Title:** Summary#2 of discussion on multi-carrier UL Tx switching scheme

**Document for:** Discussion and Decision

# Introduction

This contribution is the intermediate summary of following email discussion on multi-carrier UL Tx switching schemes for GTW session on 17th May.

//This one is to use NWM – please use RAN1-109-e-NWM-R18-MC\_Enh-02 as the document name

[109-e-R18-MC\_Enh-02] Email discussion on multi-cell UL Tx switching by May 20 – Hiroki (DOCOMO)

* Check points: May 12, May 18, May 20

# Summary of proposals

## 3.1. Whether to specify UL Tx switching schemes across up to 3 or 4 bands in Rel-18

The moderator proposes to make observations based on the evaluation results in submitted contributions regarding the gain of UL Tx switching across 3 or 4 bands compared with UL Tx switching across 2 bands, and the moderator also proposes to make a working assumption to specify UL Tx switching schemes across 3 bands and across 4 bands in Rel-18 with clarifying some criteria for designing schemes and revisiting the WA.

After the third-round email discussion, companies’ feedbacks can be summarized as below.

* Regarding the observation,
  + Fine with the proposed observation
    - Apple, IDC, New H3C, FJT, CT, DCM
* Regarding the working assumption,
  + Fine to make the working assumption
    - IDC, New H3C, Xiaomi, CMCC, vivo, LG, FJT, CT, MTK, Samsung, DCM
    - With clarification on “at least for CA”
      * ZTE
      * Objected by HW
    - To address concerns, suggest modifying the WA as design principle
      * FJT
    - Suggest revising the first sub-bullet to clarify that it is applicable to concurrent transmission only
      * HW
  + Not fine to make the woring assumption
    - Should wait for RAN4’s feedback especially on switching period/complexity
      * QCM, Apple, Intel
  + Send LS to RAN4 to ask their feedback on the switching period
    - Apple, Intel, LG, DCM

Based on the above situation, the moderator would like to focus on making observation and sending LS to RAN4 based on the evaluation results and analyses at this moment. It seems no objection to the contents of proposed observations, and we can ask RAN4’s feedback on potential increase of switching period and complexity in the case of UL Tx switching across 3 or 4 bands, with sharing the alternative switching mechanism discussed in RAN1. In addition, according to the discussion on the proposal in section 3.8, we can ask RAN4’s input on the UE behavior/assumption during switching period in case of Rel-18 UL Tx switching across 3 or 4 bands.

**Proposed observation**

* **Four contributions (3136, 4724, 4909, 5131) from three companies show their evaluation results on UL Tx switching across 3 or 4 bands at RAN1#109-e meeting.**
  + **All evaluation results show the performance gain of UL Tx switching across 4 bands compared with UL Tx switching across 2 bands, assuming TDD bands with different TDD UL/DL configurations are included in 4 bands.**
    - **Evaluation results in 3136 show the performance gain of UL Tx switching across 4 bands compared with UL Tx switching across 3 bands.**
    - **Evaluation results in 4724 show that the performance gain of UL Tx switching across 4 bands compared with UL Tx switching across 2 bands depends on achievable switching period, and the longer switching period for UL Tx switching across 4 bands compared with UL Tx switching across 2 bands leads to reduction of the performance gain. Other evaluation results did not consider the impact of longer switching period for UL Tx switching across 4 bands compared with UL Tx switching across 2 bands.**
    - **Evaluation results in 5131 observe that the gain highly depends on the scheduling mechanism.**
    - **The range of performance gains shown in four contributions varies depending on the simulation assumptions.**

**Proposed agreement**

* **Send LS to RAN4 to ask their feedback on the potential increase of switching period and complexity in the case of UL Tx switching across 3 or 4 bands**
  + **In the LS, observations based on the evaluation results and altenarive switching mechanisms discussed in RAN1 are captured for the information to RAN4**
  + **In the LS, RAN1 also asks RAN4 feedback on whether following assumption can be considered as baseline UE assumption/behavior even in case of the UL Tx switching across 3 or 4 bands**
    - **When one of the the two Tx chains is triggered to switch from one band to another band, another Tx chain is also not expected to be used for transmission during the switching period (for any of bands)**

**Proposed working assumption**

**Alt.1**

* **Specify UL Tx switching schemes across 3 bands and across 4 bands in Rel-18**
  + **The supported cases by the UE for Tx switching across 3 or 4 bands are reported as UE capability.**
    - **FFS: details of the UE capability reporting.**
  + **This WA can be revisited if RAN4 input is available e.g., RAN4 identifies longer switching period is required for UL Tx switching across 3 or 4 bands compared with that across 2 bands**
  + **Strive for minimizing the increase of implementation complexity and workload for supporting UL Tx switching across 3 bands and 4 bands e.g., by reusing Rel-16/17 UL Tx switching mechanism as much as possible and striving for a common solution between UL Tx switching across 3 bands and across 4 bands**

**Alt.2**

* **If UL Tx switching schemes across 3 bands and across 4 bands in Rel-18 is specified, the following design principle is considered.**
  + **The supported cases by the UE for Tx switching across 3 or 4 bands are reported as UE capability.**
    - **FFS: details of the UE capability reporting.**
  + **This WA can be revisited if RAN4 input is available e.g., RAN4 identifies longer switching period is required for UL Tx switching across 3 or 4 bands compared with that across 2 bands**
  + **Strive for minimizing the increase of implementation complexity and workload for supporting UL Tx switching across 3 bands and 4 bands e.g., by reusing Rel-16/17 UL Tx switching mechanism as much as possible and striving for a common solution between UL Tx switching across 3 bands and across 4 bands**

## 3.2. Whether to support inter-band UL CA Option 1 and Option 2 in Rel-18

The moderator proposes to make agreements to clarify target scenarios of Rel-18 UL Tx switching if it is to be specified. The first proposed agreement is to support both switched UL and dual UL as in Rel-16/17 UL Tx switching for inter-band CA case. During the discussion in GTW session on 13th May, the moderator proposed to discuss scenarios of inter-band CA without SUL and scenarios of inter-band CA + SUL separately. However, some companies could not accept such approach and they prefer to clarify that the existing SUL configurability in CA framework is reused for scenarios with SUL. Therefore, the moderator updated the proposal according to such request.

After the third-round email discussion, companies’ feedbacks can be summarized as below.

* Fine with the FL proposal
  + IDC, New H3C, Xiaomi, FJT, CATT, CT, MTK, HW
* Not fine with the FL proposal (prefer original proposal)
  + SUL related part should be discussed in the next section
    - QCM, Apple, CMCC, vivo, LG, Samsung, E///, DCM
  + Companies have different understandings on “existing SUL configurability in CA framework” and hence it should be clarified
    - ZTE

Based on the above situation, the moderator thinks it seems still controversial due to different views on SUL among companies although the intension of this proposal is for inter-band CA without SUL scenarios. As in section 3.3, since it seems agreeable to support at least some scenarios of inter-band CA + SUL (such as scenarios with only one SUL) if Rel-18 UL Tx switching is supported, this proposed agreement can be discussed with the proposed working assumption in section 3.3.

**Proposed agreement (to be copied to 3.3)**

* **If Rel-18 UL Tx switching is supported, both inter-band UL CA Option 1 (i.e., switched UL) and Option 2 (i.e., dual UL) are considered to define necessary mechanisms**
  + **Note: it does not imply SUL is precluded. [For SUL, the existing SUL configurability in CA framework is reused.]**

## 3.3. Whether to support inter-band UL CA + SUL scenario(s) in Rel-18

The next proposal is about inter-band UL CA + SUL scenarios. Since companies’ views are a bit diverse, e.g., some companies argued it should be naturally supported while some companies argued it should be lower priority. The moderator prepared two alternative working assumptions according to those companies’ views, and the moderator asks some questions on SUL configurability in CA framework to check the understanding among companies.

After the third-round email discussion, companies’ feedbacks can be summarized as below.

* Fine with the Alt.1 working assumption
  + QCM, Apple, IDC, Intel, SPRD, New H3C, FJT, LG, vivo, Samsung, E///, DCM
  + Open to support inter-band CA+SUL at least for 3 bands case as lower priority
    - ZTE
  + Not fine with Alt.2 working assumption (SUL+SUL case)
    - QCM, ZTE, Apple, Intel, SPRD
  + Open to support SUL+SUL case or suggest FFS for SUL+SUL case
    - New H3C, CATT
  + Prefer to remove inter-band CA Option 2 + SUL (but ok to keep if majority is ok)
    - Intel
* Fine with the Alt.2 working assumption
  + any serving cell in UL CA can be configured with a SUL carrier, and UL transmission on SUL band and UL transmission on non-corresponding NUL band can be done. No need to restrict supported scenarios in spec and it is subject to UE capability
    - HW

Based on the above situation, it seems companies would have different understanding on “SUL configurability in existing CA framework”. It should be agreeable to support at least some scenarios of inter-band CA + SUL (such as scenarios with only one SUL) if Rel-18 UL Tx switching is supported. In that sense, the moderator suggests changing the main bullet from “~ scenarios are supported” to “~ scenarios are considered to define necessary mechanisms” so that companies can discuss necessary mechanisms for some different scenarios where some differences on the mechanism may exist, while other scenarios are not precluded as long as no specific handling is necessary for the scenarios.

**Proposed working assumption**

* **If Rel-18 UL Tx switching is supported, both inter-band UL CA Option 1 (i.e., switched UL) and Option 2 (i.e., dual UL) are considered to define necessary mechanisms**
  + **Note: it does not imply SUL is precluded. ~~[For SUL, the existing SUL configurability in CA framework is reused.]~~**
* **If Rel-18 UL Tx switching is supported, at least following inter-band UL CA + SUL scenarios are considered to define necessary mechanisms in addition to inter-band UL CA without SUL scenarios in Rel-18**
  + **{SUL band + corresponding NUL band} + other NUL band (if UL Tx switching across 3 bands is supported)**
  + **{SUL band + corresponding NUL band} + other NUL band + other NUL band (if UL Tx switching across 4 bands is supported)**
  + **Note: defining necessary mechanisms to support inter-band UL CA without SUL and inter-band UL CA Option 1 + SUL (which can reuse mechanisms for inter-band UL CA Option 1 without SUL) are prioritized, and if time allows, necessary mechanisms to support inter-band UL CA Option 2 + SUL can be discussed**
  + **Note: this does not preclude the support of other scenarios of inter-band UL CA + SUL in Rel-18 as long as no specific handling is necessary for the scenarios**

## 3.4. Whether to support inter-band UL CA + EN-DC scenario(s) in Rel-18

(Already closed with following conclusion)

**Conclusion**

* **EN-DC cases are out of scope for Rel-18 UL Tx switching**

## 3.5. Whether to support “UL transmission on a carrier without corresponding DL carrier” in Rel-18

(Already closed with following conclusion)

**Conclusion**

* **UL only cell cases are out of scope for Rel-18 UL Tx switching**

## 3.6. Whether to support inter-band UL CA with intra-band contiguous carriers within band(s) in Rel-18

The next proposal is about inter band UL CA with intra-band contiguous carriers within a band. In Rel-17 UL Tx switching between band A and band B, the band B can have two contiguous aggregated carriers, and the same state of Tx chain is applied to the intra-band two contiguous carriers. For Rel-18 UL Tx switching, it is not clarified in the WID that whether to support inter-band UL CA with intra-band contiguous carriers within a band, how many bands can have intra-band contiguous carriers, and how many contiguous carriers within a band can be supported. Therefore, the moderator proposes to support one out of 3 or 4 bands can have up to 2 contiguous carriers within a band as in Rel-17 assumption considering the limited TUs, with a note to clarify that RAN1 spec would be described agnostic to number of carriers within a band according to some companies’ request.

After the third-round email discussion, companies’ feedbacks can be summarized as below.

* Fine with the FL proposal
  + Apple. IDC, SPRD, New H3C, FJT, MTK, Samsung, DCM
  + Suggest removing the third bullet and it should be left to the editor and rapporteur
    - QCM, Intel, CATT
    - Objected by HW
  + Suggest adding a note “the spec does not restrict which band can have up to two contiguous carriers within the band”
    - LG
  + Suggest changing the first bullet to “Rel-17 mechanism on whether/when a UL Tx switching occurs or not is reused”
    - HW
* Not fine with the FL proposal
  + Should not restrict to only one band to have contiguous carriers
    - ZTE, Xiaomi, vivo, CT
  + Should clarify that only non-SUL band can have contiguous carriers
    - ZTE
    - Objected by HW
  + The first bullet should be a note
    - ZTE

Based on the above situation, the moderator suggests some modifications according to the feedbacks so far. In addition, considering that there are several companies prefer to not restrict the number of bands with contiguous carriers to only one, the proposal can be for working assumption and companies can be encouraged to investigate whether there is any issue/impact if there are more than one band with contiguous carriers. Alternatively RAN1 can ask RAN4’s input on the number of bands with contiguous carriers.

**Proposed working assumption**

* **If Rel-18 UL Tx switching is supported, for Rel-18 UL Tx switching across up to 3 or 4 bands, there can be up to two contiguous carriers within a band, and the same state of Tx chain is applied to the intra-band contiguous carriers within the band**
  + **Note: A single RF chain would cover both carriers in one band and UE jointly checks the configuration of the two carriers and use the maximum ports number among the scheduling for the two carriers on the band to decide whether to switch or not (i.e., the Rel-17 mechanism on whether/when a UL Tx switching occurs or not is reused)**
  + **One band can have up to two contiguous carriers within a band among 3 or 4 bands**
    - **Companies are encouraged to investigate whether there is any issue/impact if there are more than one band with contiguous carriers**
    - **Note: the spec may not restrict which band can have up to two contiguous carriers within the band**
  + **Note: RAN1 spec may be described agnostic to number of carriers within a band**

## 3.7. Whether to support UL Tx switching with multiple TAGs in Rel-18 and how to proceed the discussion between RAN1 and RAN4

The next discussion point is about multiple TAGs. At the RAN#95-e, it was agreed to add a note that “Note: Extension of TX switching for 2 bands to multiple TAG configurations is included in the scope. The work is limited to RAN4”. Although the note said that “the work is limited to RAN4”, it seems some companies consider it is better to discuss on the impact of multiple TAGs in RAN1 to facilitate the discussion in RAN4 since RAN4 discussion on this WI will start in Q3 2022 while RAN1 discussion starts in Q2 2022. In addition, it is not clear which WG should lead the discussion on whether to support UL Tx switching for 3 or 4 bands with multiple TAGs. Therefore, the moderator proposed to clarify which WG should lead the discussion. In addition, the moderator asked companies to provide views on whether any potential RAN1 impact to support UL Tx switching across 2 bands is identified and same for across 3 or 4 bands case. Based on the feedbacks, the proposed conclusion was discussed in GTW session on 13th May and in the third-round email discussion.

After the third-round email discussion, companies’ feedbacks can be summarized as below.

* Fine with the proposed conclusion
  + ZTE, IDC, SPRD, New H3C, Xiaomi, vivo, CATT, CT
  + Suggest removing the first sub-bullet
    - QCM, Apple, Intel, CMCC, FJT, LG, MTK, Samsung, HW
  + Fine to remove the first sub-bullet
    - ZTE, IDC, CT
  + Suggest clarifying whether “UL CA” in the first sub-bullet refers CA with SUL or CA without SUL or both
    - Vivo, HW
  + Suggest clarifying in first sub-bullet that for 2-bands and 2-TAGs
    - E///
  + Suggest removing the bracket from the third sub-bullet
    - QCM
  + Suggest removing the third sub-bullet
    - LG

Based on the above situation, the moderator thinks RAN1 can discuss following updated proposal.

**Proposed conclusion**

* **It is RAN1’s understanding that RAN4 should lead the discussion on whether to support UL Tx switching with multiple TAGs for both 2 bands case and more than 2 bands case**
  + **~~At least for UL CA, it is RAN1 understanding that there is no RAN1 specification impact~~**
  + **For further discussion in RAN1 with regards to UL Tx switching with multiple TAGs, it will be discussed only if triggered by RAN4**
  + **If it is decided to support UL Tx switching with multiple TAGs, it is RAN1's working assumption that the number of TAGs should be limited to up to 2**

## 3.8. Clarifications on some general assumptions for Rel-18 UL Tx switching

Based on some proposals in the contributions, the moderator would like to try to make some clarifications on general assumptions for Rel-18 UL Tx switching. One would be quite obvious that the 2-ports UL transmission on the NR band is possible only when the two TX chains are linked to one NR band. Another one seems a bit controversial that when one of the two Tx chains is triggered to switch from one band to another band, whether another Tx chain is also not expected to be used for transmission for any band during the switching period. The moderator proposes to make the second point as working assumption so that companies can also investigate other possible assumptions.

After the third-round email discussion, companies’ feedbacks can be summarized as below.

* Fine with the FL proposal
  + IDC, Intel, vivo, LG, CATT, CT, MTK, Samsung, DCM
* Not fine with the FL proposal
  + Should remove WA part
    - QCM, ZTE, Apple, New H3C, Xiaomi

Based on the above situation, the moderator thinks RAN1 can discuss following updated proposal i.e., focusing on the first sub-bullet. The WA part can be included in the potential LS to RAN4 as proposed in the section 3.1.

**Proposed agreement**

* **If Rel-18 UL Tx switching is supported, following assumptions are applied for Rel-18 UL Tx switching across up to 3 or 4 bands**
  + **Only when the two Tx chains are linked to one NR band, the 2-ports UL transmission on the NR band is possible**
  + **~~(Working assumption) It is assumed as a baseline UE capability that when one of the the two Tx chains is triggered to switch from one band to another band, another Tx chain is also not expected to be used for transmission during the switching period~~**
    - **~~Other advanced UE capability/assumption can also be considered~~**

## 4.1. Potential mechanisms for dynamic Tx carrier switching across the configured bands

Based on the proposals in contributions submitted to this meeting, the moderator tried to list up potential mechanisms for Rel-18 UL Tx switching so that companies are encouraged to investigate which mechanism is better/necessary and to provide such analysis in their contributions for next meeting to facilitate the discussion. The moderator believes it is good to emphasize all proposals on the table to facilitate the discussion considering limited TUs for this WI.

After the third-round email discussion, companies’ feedbacks can be summarized as below.

* For the first proposal
  + Fine with the FL proposal
    - QCM, Apple, IDC, Intel, SPRD, New H3C, Xiaomi, CMCC, vivo, LG, CATT, CT, MTK, Samsung, HW, DCM
    - Suggest adding a note “In addition to the UE/gNB complexity reduction, performance reduction caused by any scheduling restriction can also be taken into account for down-selection”
      * LG
  + Not fine with the FL proposal
    - Suggest removing the last note
      * ZTE
      * Objected by HW
* For the second proposal
  + Fine with the FL proposal
    - QCM, Apple, IDC, SPRD, New H3C, Xiaomi, CMCC, LG, CATT, MTK, Samsung, HW, DCM
    - Suggest clarifying whether proposals are applicable to Alt.1 in the first proposal only or all alternatives in the first proposal
      * Xiaomi
    - Suggest adding a note “In addition to the UE/gNB complexity reduction, performance reduction caused by any scheduling restriction can also be taken into account for down-selection”
      * LG
  + Not fine with the FL proposal
    - Not as agreement, just list proposals in the chair note
      * ZTE, vivo
    - Need further discussion
      * Intel, CT

Based on the above situation, the moderator thinks RAN1 can discuss following updated proposals from the first one. According to the feedbacks, the second proposal can be captured as observation that listed proposals are identified in RAN1#109-e and companies are encouraged to investigate pros and cons of the proposals.

**Proposed agreement**

* **Companies are encouraged to investigate pros and cons of following possible mechanisms for dynamic Tx carrier switching across the configured bands, and RAN1 strives for the down-selection at RAN1#110**
  + **Alt.1: Dynamic Tx carrier switching can be across all the supported switching cases by the UE and based on the UL scheduling, i.e., via UL grant and/or RRC configuration for UL transmission**
  + **Alt.2: NW indicates 2 bands out of the configured bands (3 or 4 bands) via DCI or MAC-CE, and dynamic Tx carrier switching between indicated bands is same as Rel-17**
  + **Alt.3: One anchor band is selected among configured bands (3 or 4 bands), and dynamic Tx carrier switching can be performed only from the anchor band to a non-anchor band and from a non-anchor band to the anchor band**
  + **Note: Other mechanisms are not precluded**
  + **Note: In addition to the UE/gNB complexity reduction, performance reduction caused by any scheduling restriction can also be taken into account for down-selection**
  + **Note: separate down-selection for switched UL and dual UL is not precluded**

**Proposed observation**

* **Following proposals to address the concern on UE/gNB complexity increase due to UL Tx switching across larger number of bands compared with Rel-16/17 are identified in contributions submitted at RAN1#109-e, and companies are encouraged to investigate pros and cons of the proposals so that one or some of them may be down-selected after the down-selection of the mechanism for dynamic Tx carrier switching across the configured bands**
  + **UE can report the supports of only some of concurrent UL cases (combinations of 2 bands for concurrent UL transmissions)**
  + **Switching across 0/1/2 ports is supported only for 2 configured bands out of 3 or 4 configured bands and other bands support switching across 0/1 port only**
  + **Only switching across 0/1 port is supported across all configured bands when 3 or 4 bands are configured**
  + **Prioritization rules between uplink carriers are specified**
  + **No restriction on the UEs choice of MIMO capability on any of the bands/CCs involved in the UL Tx switching band combination is introduced**
  + **After one RF state switch, the next RF state switch must occur after 14 symbols or later (FFS: which SCS is assumed for the symbol duration)**
  + **Note: Other solutions are not precluded**
  + **Note: each proposal assumes certain mechanism for dynamic Tx carrier switching across the configured bands, and hence some or all of the proposals may not be necessary depending on the down selection of the mechanism for dynamic Tx carrier switching across the configured bands**

## 4.2. Potential switching configuration(s) to be supported for Rel-18 UL Tx switching

In Rel-16, it was assumed that one of the two Tx chain is fixed to one band and another Tx chain can switch between the band and another band, i.e., called as 1Tx-2Tx switching. In Rel-17, in addition to the 1Tx-2Tx switching, 2Tx-2Tx switching where both of two Tx chains can switch between 2 bands was supported. For Rel-18, it is not clarified in the WID that which switching configuration(s) is/are supported. Therefore, the moderator tried to list up all potential switching configurations for the case with 3 and 4 bands to facilitate further investigation.

After the third-round email discussion, companies’ feedbacks can be summarized as below.

* Fine with the FL proposal
  + IDC, Xiaomi, LG, CATT
  + Suggest adding a note “The Spec should not restrict which Tx chain is fixed or switched across certain bands. It is up to UE implementation.”
    - QCM, IDC, New H3C, CT
  + Suggest using the wording within parentheses
    - CT
* Not fine with the FL proposal
  + Should discuss after down-selection on switching mechanism
    - ZTE, Apple, Intel, CMCC, vivo
  + Suggest removing the first note
    - ZTE
  + Suggest capturing possible configurations as proposal not as agreement
    - ZTE

Based on the above situation, we can try to capture possible switching configurations as observation in the chair note, like the second part of proposal in section 4.1.

**Proposed observation**

* **Following possible switching configurations can be considered, and RAN1 will discuss the down-selection after making some progress on the discussion on the switching mechanism**
  + **For 3 bands case**
    - **Switching configuration.3-1: all the 3 bands support up to 2Tx**
    - **Switching configuration.3-2: only 1 band out of 3 bands support up to 2Tx**
    - **Switching configuration.3-3: only 2 bands out of 3 bands support up to 2Tx**
  + **For 4 bands case**
    - **Switching configuration.4-1: all the 4 bands support up to 2Tx**
    - **Switching configuration.4-2: only 1 band out of 4 bands support up to 2Tx**
    - **Switching configuration.4-3: only 2 bands out of 4 bands support up to 2Tx**
    - **Switching configuration.4-4: only 3 bands out of 4 bands support up to 2Tx**
  + **Note: separate down-selection for switched UL and dual UL is not precluded**
  + **Note: In addition to the UE/gNB complexity reduction, performance reduction caused by any scheduling restriction can also be taken into account for down-selection**
  + **Note: The Spec should not restrict which Tx chain is fixed or switched across certain bands. It is up to UE implementation.**